Rotating Antenna Tests at DSS 12

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Tests were conducted using a rotating antenna on the collimation tower at DSS 12 (Echo Deep Space Station) to simulate the rotating Pioneer F spacecraft. Specific measurements were taken to determine the degradation in telemetry bit error rate and doppler quality as a result of the rotation and misalignment of the rotating antenna relative to the receiving antenna.

I. Introduction

The *Pioneer F* spacecraft will utilize a conical scan (CONSCAN) system to allow automatic pointing of its antenna at the earth. The spacecraft will rotate continuously about the roll axis during the mission, and will consequently present some characteristics to a ground station not seen on previous missions. A rotating antenna on the collimation tower at DSS 12 was used to simulate the spacecraft so as to allow quantitative measurement of the effect of CONSCAN on telemetry bit error rate and doppler quality.

The useful property of a CONSCAN system is production of an AM signal in any direction of observation not coincident with the axis of rotation. To do so requires that the antenna be offset slightly so that rotation causes the line representing the direction of maximum radiation from the antenna to describe a right circular cone whose vertex is at the antenna and whose apex angle is twice the offset angle. At any point on the axis of rotation, also the axis of the cone, the signal strength remains constant during rotation, while in any other direction the signal strength will change in a manner which can be predicted by analysis of the radiation pattern of the rotating antenna. At any off-axis point the observed signal strength will be a sinusoid at the rotational frequency, expected to be about 4.8 rpm for *Pioneer F*, plus, so long as the observation point sees only the main lobe of the radiation pattern during one rotation, harmonics of relatively low amplitude.

The *Pioneer F* spacecraft, with a CONSCAN antenna system whose axis is the rotational axis, will thus see an AM signal derived from the uplink transmission whenever the antenna is not pointed exactly at the earth. Upon ground command the spacecraft will be able to point itself at the earth by on-board processing of the AM waveform to produce signals for the orientation jets. Intervals of some days will elapse between such maneuvers so that precession of the inertial attitude between spacecraft and earth will cause an increase in the amplitude of the CONSCAN AM signal. Such a variation in received signal level at a ground station will affect the data quality, in particular that of telemetry bit error rate and doppler phase jitter, neither of which is a simple linear function of signal strength. The rotating antenna tests were undertaken with an idea of measuring such degradations for different values of received signal strength and CONSCAN antenna misalignment.

Conventional techniques should suffice for counting telemetry bit error rates so long as the counting interval is long compared to the CONSCAN rotational rate. Previously employed tests to measure doppler jitter, however, are inappropriate, since they measure only a static value and are inapplicable to a situation of varying signal strength. In addition, previous doppler tests were for zero frequency shift as is normally experienced over the path transmitter-collimation tower-receiver. One circularly polarized antenna rotating relative to another always produces a doppler shift since the polarization vector rotates at the carrier frequency plus or minus, depending upon the relative sense, the frequency of antenna rotation. Doppler count as a function of time should therefore be a straight line with slope proportional to the rotation rate. It was decided the most meaningful analysis of doppler quality would be the standard deviation between data points and a fit of the data to a straight line.

II. Test Procedures

A. Preliminary

A four-foot-diameter antenna with circularly polarized feed was obtained to serve as the rotating antenna. Using the JPL antenna range, the feed was focused by adjusting for the narrowest possible main lobe of radiation. Since the four-foot antenna corresponds in size to neither of the directive antennas that will be on *Pioneer F,* it is necessary to scale all parameters. *Pioneer F* offset of the antennas is 1 dB, which value is caused by skew of 0.3 times the 3-dB beamwidth. The four-foot antenna had an S-band beamwidth of nine degrees, requiring offset of 2.7 degrees. The antenna was bolted to a rotating mount, allowing continuous rotation by means of a rotary joint. Rotation rate was adjustable. A shim was placed between antenna and mount to offset the antenna axis by 2.7 degrees. Handwheels on the mount permitted motion of the rotating antenna in azimuth and elevation. The assembly, consisting of antenna plus rotating mount, was installed near the top of the DSS 12 collimation tower. Cables were run to the room at the base of the tower for antenna feed and rotation control.

B. Station Configuration

The configuration used during the tests is shown in Fig. 1. The *Pioneer* GOE (ground operational equipment) was used to simulate the functions of the spacecraft. Although the GOE characteristics are more that of *Pioneers* previous to *F,* they are quite close to those desired, besides being all that was available. Two-way lock was maintained over the path transmitter–GOE transponder–receiver for all data runs. The doppler data from the extractor was fed into the TDH and then was recorded on magnetic tape at the rate of one sample per second by the DIS computer. The tape was later reduced by data analysis programs. A test bit stream of coded telemetry data was generated by the GOE Data Format Generator at the collimation tower and used to modulate the transponder transmitter. Modulation index was adjusted for 6.9-dB carrier suppression, the same as expected for *Pioneer F.* After being received inside the control room, the telemetry was demodulated by GOE and compared by the TCP computer with a locally generated bit stream. The TCP counted bit errors and output the results on typewriter. The procedure whereby the actual data stream was generated twice was necessary since no cable line to use as a reference was available between collimation tower and control room.

C. Data Collection

Receiver AGC voltage as a function of signal strength was calibrated at the beginning of each day of the test. The rotating antenna was adjusted to produce signals of a particular AM characteristic; values of 0, 2, 4, and 6 dB peak-to-peak were used during the test. These adjustments were made with the ground transmitter turned off, for the safety of the individual on the tower, and were done while receiving a strong signal in the station receiver. In this manner the received signal could be displayed on a chart recorder to aid in adjusting the antenna offset to the desired level. After setting the antenna misalignment, two-way lock was established and the received signal at the transponder attenuated to -110 dBm. Maintaining such a strong level should ensure the preponderance of the jitter seen to be a product of the station receiver and not the transponder. Attenuation was inserted in the transponder transmitter to produce the desired signal levels at the station receiver. Nominal values of -130, -140, -150, and -160 dBm were used. Digital voltmeter AGC readings, which varied at the CONSCAN rotational frequency rate, were averaged to calculate the mean value at a given attenuator setting. Data runs were typically 15 minutes for a particular CONSCAN amplitude and received signal level.

III. Results

Degradation of doppler quality and of telemetry bit error rate in the presence of CONSCAN was noted. That is, both quantities were worse with CONSCAN at an averaged signal level than at the same signal level in the absence of CONSCAN. More quantitative results must await further analysis and are not yet available. Two interesting factors of importance to operational tracking of *Pioneer F* did appear, however, and will be mentioned here. First, the CONSCAN AM can be determined to no better than 0.1 dB p–p because of the presence of modulation at a frequency approximately 72/minute corresponding to the maser cryogenic pump. This is of consequence principally when atempting to boresight the CONSCAN system. Second, the narrow AGC position of the station receiver will not follow variations at the CONSCAN rate, and either medium or wide AGC must be used with resultant production of noisier data.

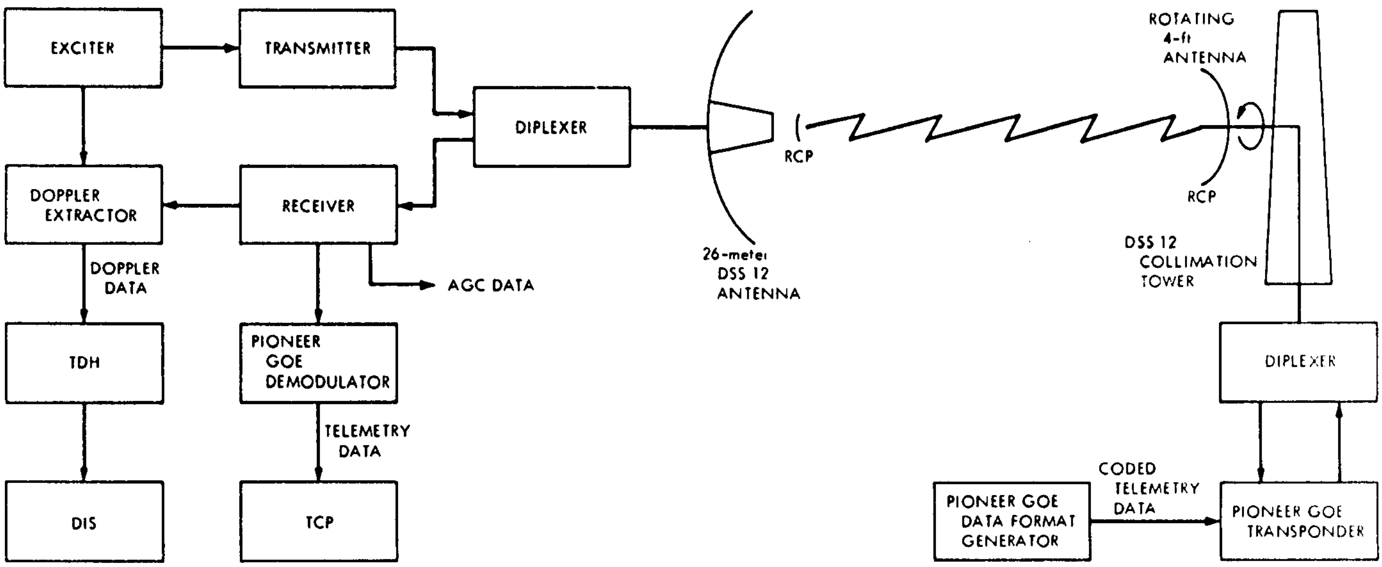

Fig. 1. Configuration used for rotating antenna tests